Water Quality Mathematical Expressions & Relationships

A Collection of Water Quality Mathematical Expressions and Relationships

Gram (g), kilogram (Kg), milligram (mg), microgram (ug) - These are units of mass (weight) in the metric system. The basic unit is the gram (0.002205 lb.). 1000 grams equals 1 kilogram (2.205 lb). A milligram is 1/1000th of a gram (i.e. 1000 mg equal 1 g). A microgram is 1/1000th of a milligram and 1/1,000,000th of a gram (i.e.1000 ug equals 1 mg and 1,000,000 ug equals 1g).

Meter (M), centimeter (cm) - these are selected metric units of length. We can consider the basic unit of length to be the meter (1.094 yards; 39.37 inches). 1 centimeter (0.3937 inches) is 1/100th of a meter (i.e. 100 centimeters equal 1 meter).

Liter (L), milliliter (ml), microliter (ul) - these are metric units of volume and they work like the units of mass and length described above. If we say that the basic unit of volume is the liter (1.057 quarts), then a milliliter equals 1/1000th of a liter and a microliter equals 1/1,000,000th of a liter. So, there are 1000mL in 1 liter, 1000uL in 1 milliliter and 1,000,000mL in 1 liter. There are a couple of secrets. One is that 1 milliliter equals 1 cubic centimeter (cc; imagine a cube 1 centimeter to a side). Another, it is assumed that 1 milliliter of water equals 1 cubic centimeter of water, which weighs 1gram! (Red Herring: "A pint's a pound the world around.") In any case, the assumed mass of 1 liter of water equals 1 kilogram, 1000 grams, 1,000,000 milligrams or 1,000,000,000 micrograms.

Parts per million (ppm) - this is a generic unit of measure in the sense that it can represent a lot different units of measure (e.g. mg/L, ug/ml, mg/Kg, lb/acre), therefore a ppm equals one part of something per million parts of something else. So if you have water quality data in mg/L, that data is equivalent to ppm (i.e. 50mg Calcium/L = 50 mg Calcium per 1,000,000 mg/L of water = 50 ppm Calcium). By the way, if you have soil test data in parts per million you can convert that to lb/Acre by multiplying by 2. It is assumed that an acre furrow slice (8" thick) of soil weighs 2,000,000 pounds.

Parts per billion (ppb) - similar in concept to ppm except they are smaller and consequently there can be more of them, 1 ppm = 1000 ppb If you have 0.010 mg lead/L this equals 0.010 ppm lead or 10 ppb lead (0.010 ppm x 1000ppb/ppm).

Milliequivalents per liter (meq/L) - meq/L is another method of expressing concentration, when the analytes are dissolved and disassociated in solution. meq/L is also equal to millimoles of charge per liter (mM+/L or mM-/L depending on valence). A mole contains 6.022 x 1023 molecules; for example a mole of calcium contains 6.022 x

1023 atoms of calcium. Therefore, a millimole is 1/1000th of a mole. To calculate meq Ca/L from the reported value in mg/L, we must know something about calcium.

- Calcium has a molecular weight of 40.08 grams/mole
- Calcium has a valence of +2
- The equivalent weight = (40.08grams/mole)/(2 equivalents/mole) = 20.04 grams/eq
- To convert to mg/meq you simply multiply g/eq by 1000 mg/g and divide by 1000 meq/eq, thus g/eq = mg/meq
- If your sample contains 30 mg Ca/L, what is the concentration in meq/L?

Meq Ca/L = (30 mg Ca/L)/(20.04 mg/meq) = 1.50 meq Ca/L

Electrical Conductivity (EC), Specific Conductance - simply defined this is a measure of a solution's ability to conduct electricity. It is the reciprocal of a solution's electrical resistance. The units of resistance are ohm-cm. The units for conductance is Seimen/meter (S/m). Not too long ago EC was measured in units of mho/cm. It turns out that Seimen/meter equals mhos/meter (mhos/m), microSeimen/centimeter (uS/cm) is equivalent to umho/cm and milliSeimen/centimeter (mS/cm) is equivalent to millimho/cm (mmho/cm). No matter what the term appearing on our reports (Electrical Conductivity (EC), Specific Conductance, Conductance, Conductivity, etc,), we report uS/cm, or umhos/cm corrected to 25°C.

Total Dissolved Solids (TDS) - this is also a measure of the salts dissolved in water. Not surprisingly, there is a relationship between TDS and EC. Generally speaking the TDS in mg/L is about 2/3-3/4 of the EC measured in uS/cm. So, now you have a way of calculating TDS if you know the EC; TDS ~ 0.7 EC.

Hardness - hardness is defined as the sum of the calcium (Ca) and magnesium (Mg) concentrations, both expressed as calcium carbonate in milligrams per liter (mg/L). To calculate hardness from the calcium and magnesium concentrations (mg/L), we must first convert these concentrations to milliequivalents/Liter (meq/L). This conversion in terms of concentration allows the calcium and magnesium to be added together.

Often water treatment technicians express hardness with units of grains per gallon. 1grain (gr) per gallon (gal) = 17.1 mg/L = 17.1 ppm. Conversely, 1 mg/L = 0.0585 gr/gal. So if you know your water's hardness in terms of grains per gallon you can convert that value to mg/L or ppm by multiplying by 17.1. In the reverse, if you have the value in terms of mg/L or ppm multiply that value by 0.0585 to obtain that value in terms of gr/gal.

Let's look at an example calculation for water containing 35 mg Ca/L and 22 mg Mg/L.

Calculation of Calcium Carbonate Hardness				
Data:	**Analyte**	**mg/L**	**mg/meq**	**meq/L**
	Calcium	35	20.04	1.75
	Magnesium	22	12.16	1.81
	$CaCO_3$	----	50.05	----
To Calculate hardness as mg $CaCO_3$/L:				
meq/L = (mg/L) / (mg/meq)				
Hardness mg/L = [(meq Ca/L) + (meq Mg/L)] x [50.05]				
Substituting the data from above table,				
Hardness as mg $CaCO_3$/L = (1.75 + 1.81)(50.05) = 178 mg/L				
Now let's convert this result to grains/gallon,				
Hardness in gr/gal = (178 mg/L) / (17.1 mg/gr) = 10.4 gr/gsl				

The following table is provided for easy reference and lists the major cations and anions found in most natural water. Listed for each analyte are its valence, millimolecular weight (mg/mMole) and milliequivalent weight (mg/meq).

Cations	Valance		mMolar wt	meg wt
Calcium	+	2	40.08	20.04
Magnesium	+	2	24.32	12.16
Sodium	+	1	22.99	22.99
Potassium	+	1	39.10	39.10

Anions	Valance		mMolar wt	meq wt
Carbonate	-	2	60.01	30.01
Bicarbonate	-	1	61.02	61.02
Chloride	-	1	35.46	35.46
Fluoride	-	1	19.00	19.00
Nitrate as N	-	1	14.01	14.01
Nitrite as N	-	1	14.01	14.01
Sulfate	-	2	96.06	48.03